# Decontamination of Heavy Metal Contaminated Soils by Phytoremediation: Pot Experimentation

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## 1 Introduction

Due to the rapid growth of population and industrialization, waste has been generated in huge scale. According to food and agriculture organization of the United Nations approximately 110 million mines, industrialization and other unexploded pieces of ordnance are scattered across 64 countries on all continents, remnants of war that can have deadly consequences for farmers and heavy metals and organic contaminants released by weathering. 1.3 billion tons of municipal solid waste were generated all around the world per year up to 2012, and it is expected to rise to 2.2 billion tons annually by 2025. In the recent years, geotechnical engineers and researchers were concentrating on phytoremediation to clean up the contaminated lands.

Shorter range and longer range of spatial continuity of degradation of total petroleum hydrocarbons was shown by St. Augustin grass and Sorghum. Rye grass and St. Augustin grass decontaminated the total petroleum hydrocarbons contaminated soil 25% more than the Sorghum [1]. Methyl tertiary butyl ether (MTBE) was taken up by hybrid poplar saplings through water, half of the MTBE mass reduced through volatilization has yielded 25% reduction in aqueous MTBE concentration and 30% reduction in MTBE mass over a 1-week period which is significantly greater than the controls [2]. Hybrid poplar trees can grow significantly in Pb–Zn contaminated soils by using cattle manure as soil amendment at a pH of 6–6.3 [3]. The removal of heavy metals (Cd, Cr and Ni) from heavy metal contaminated aqueous solution with Rhizosphere consortium bacteria as amendment was 32.9, 42.5, and 16.5% at a span of 12 days by changing the pH from 4.5 to neutral [4]. Pteris Vittata

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plants have an excellent removal (68% of 220 ppb) of arsenic from arsenic contaminated water [5]. The accumulation of heavy metals (Zn and Cd) was more in the shoot portion of Transgenic Arabidopsis plants compared to wild type Arabidopsis plants [6]. The growth of wheat plant and removal of phenanthrene and pyrene was significant in both planted and unplanted contaminated soil with live micro bacterium sp. F10a inoculated pot planted contaminated soil [7]. Aspalathus linearis exudate the aluminum chelating organic acids ligands such as citric, malic, and malonic acids. Brachiaria Decumbens plant extracted the copper from the copper contaminated soil; the highest copper content was in the roots of the plant and prevents the ground water pollution by reducing the copper leachate, and this plant can be used as bio energy plant after harvesting [8]. The germination, survival, and biomass production of sunflower plant was good in both heavy metal (lead, cadmium and chromium) and organic (Phenanthrene and naphthalene) contaminated soils [9, 10]. Sunflower plant had better contaminant removal from the contaminated (phenanthrene, naphthalene, chromium cadmium, and lead) soil [11, 12]. The reduction of cadmium and lead with sunflower plant by soil amended with biochar and compost was good compared to unamended plant [11, 12]. The accumulation of zinc and copper by alfalfa plant inoculated with Pantoea Sp. Strain Y4-4 as plant growth promoting bacteria was 30.3 and 15% more compared to non-inoculated plant [13]. The cadmium content decreased in root, stem, and leaf of lavender plant by 17.5%, 43.8%, and 27%, respectively, by biochar addition to the soil contaminated with cadmium, compared to no-biochar amended plant-soil system [14]. The toxicity zones were created in the soil by using electro phytoremediation with barley as plant species [15]. Helianthus annus plant has better heavy metal (Cd, Cr and Pb) removal from the contaminated soil [16].

From the background of the study, it can be observed that there is a depth of investigations where local plants have been employed to decontaminate heavy metal contaminated soil. Hence, in the present study, an attempt has been made to utilize the local plants and study its performance in decontaminating heavy metals from the soil. Before starting the phytoremediation, a research was made in the present study, on the decontamination of low compressible clay contaminated with heavy metals without using plant species. It was observed that no reduction in heavy metal concentration was found.

## 2 Experimental Methodology

### *2.1 Soil Properties*

The soil sample collected from the farm land is red soil which is nearer to the Galiveedu (M), Kadapa (dist.) Andhra Pradesh. The geotechnical properties of soil were determined as per Indian standard code of practice and are tabulated in Table.1. The grain size distribution curve of collected soil was shown in Fig. 1.

**Table 1** Properties of soil

| S. No. | Property of soil | Value |
|---|---|---|
| 1 | Clay (< 0.002 mm) (%) | 30 |
| 2 | Silt (0.002–0.075 mm) (%) | 28 |
| 3 | Sand (0.075–4.75 mm) (%) | 33.4 |
| 4 | Fine gravel (> 4.75 mm) (%) | 8.6 |
| 5 | Organic content (%) | 3.2 |
| 6 | Specific gravity | 2.71 |
| 7 | Liquid limit (%) | 33.7 |
| 8 | Plastic limit (%) | 22 |
| 9 | Plasticity index (%) | 11.7 |
| 10 | pH of soil | 7.8 |
| 11 | Soil classification | Low compressible clay |

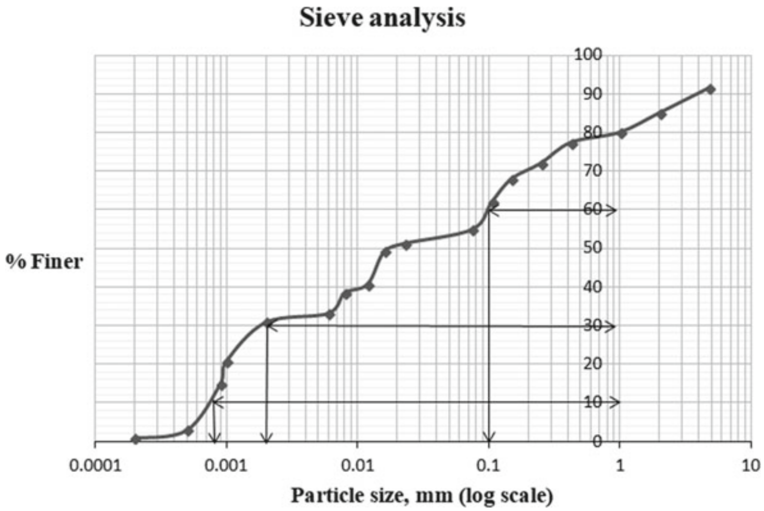


**Fig. 1** Grain size distribution curve

## 2.2 *Selected Plant Species*

So many researchers have conducted research on different plant species in different contaminated soils. But still, several regional plant species which can grow in critical environmental conditions have not been considered to conduct research in the field of phytoremediation. In this context, plant species which have been selected for this research are Setaria Italica, Sesamum Indicum, and Vigna Radiata.

**Table 2** Plant species with heavy metal contaminated soil

| S. No. | Name of the plant | Heavy metal concentration in soil (mg/kg) | | | |
|---|---|---|---|---|---|
| | | Control | Cadmium | Copper | Zinc |
| 1 | Sesamum Indicum | 0 | 150 | 800 | 1000 |
| 2 | Setaria Italica | 0 | 150 | 800 | 1000 |
| 3 | Vigna Radiata | 0 | 150 | 800 | 1000 |

### *2.3 Soil Spiking Procedure*

Heavy metal contaminated soil was prepared by adding 0.613 g of $CdCl_2$, 2.009 g of $CuSO_4$, and 2.46 g of $ZnSO_4$ for each kg of soil in separate pots to get concentration of Cd (150 mg/kg of soil), Cu (800 mg/kg of soil), and Zn (1000 mg/kg of soil). The heavy metals are mixed with deionized water (15 % water content by soil) and stirred for one hour using glass stirrer separately in a 100 ml beaker, and this solution was mixed in the clean air dried soil. The concentration of chemical contaminants in selected plant species pots was mentioned in Table 2.

The artificial heavy metal (Cd, Cu and Zn) contaminated soil was filled exactly 3 kilograms in each pot, and one set of control pots were prepared for each plant species. The seeds selected for the research were sown at a depth of ½ inch from soil surface in the pot.

### *2.4 Pot Setup and Monitoring*

Each pot was kept on separate trays to ensure that the leachate does not get mixed up. The pots were placed under sunlight to obtain the desired light intensity. The plants were grown for 28 days, and the growth was monitored. Watering was carried out every day in each pot. The locations of the pots were rotated periodically to ensure uniform light intensity to all the pots. Weekly monitoring was done to record the germination, number of plants, plant height, and contaminant removal from the contaminated soil. At the end of the period, harvested plant species were composted or incinerated.

## 3 Results and Discussion

### *3.1 Germination*

The germination of different plant species can be varied based on chemical behavior of soils. Figure 2 represents the germination percentage of three plant species in heavy

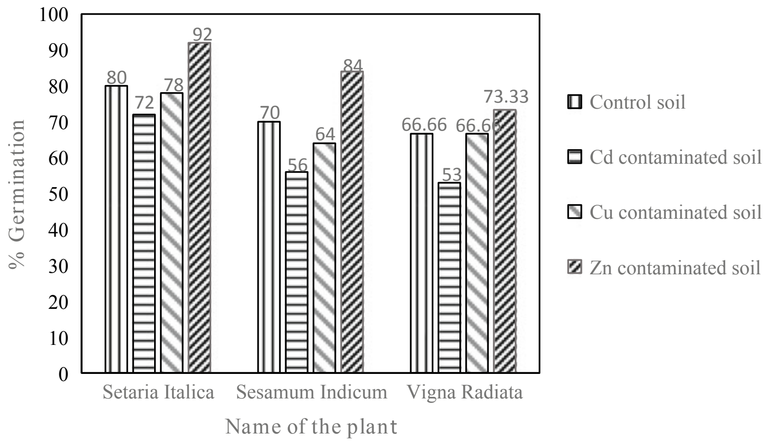


**Fig. 2** Germination percentages of plant species in different soil conditions

metal contaminated soils and control soils. Among all three plant species, Setaria Italica plant had better germination. In cadmium contaminated soil, Setaria Italica plant had 72% germination. In copper contaminated soil, Setaria Italica, Sesamum Indicum, and Vigna Radiata plants have germination percentages 78%, 64%, and 66.66%, respectively. In zinc contaminated soil, Setaria Italica plant was top with 92% germination; Sesamum Indicum and Vigna Radiata plants have 84% and 73.33%, respectively.

### *3.2 Percentage Survival of Plant Species*

The percentage survival of plant species is defined as the number of plants alive to total number of seeds germinated. The percentage survival of plant species depends on toxicity of soil, and it has been observed by health of leaves and stem portion of the plants. The percentage survival of plant species after 28 days of duration is represented in Fig. 3. The survival of Setaria Italica and Vigna Radiata plant was good in heavy metal contaminated soil.

### *3.3 Mean Heights of the Plant Species*

The height of plant species at 28 days of duration can be significantly varied, and it depends on chemical behavior of soil surrounding the rhizosphere. The mean heights of Setaria Italica, Sesamum Indicum, and Vigna Radiata plant species were represented in Fig. 4. The plant species which are in control soil is having highest growth

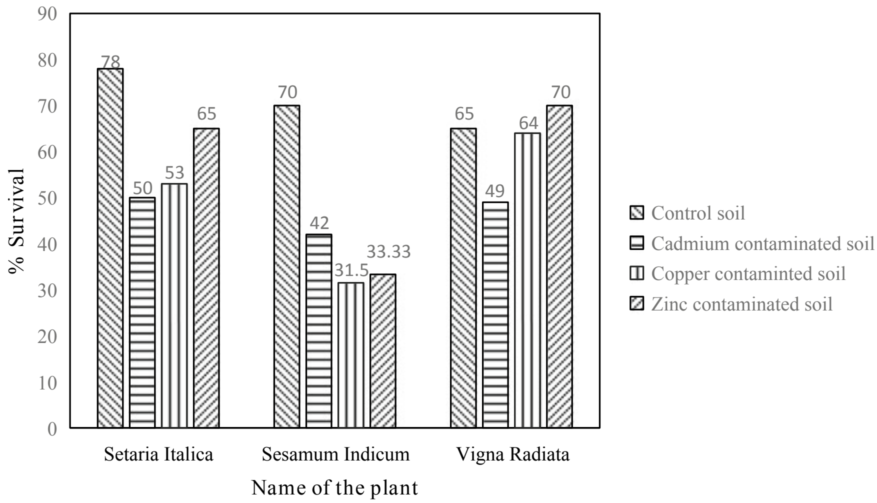


**Fig. 3** Percentage survival of plant species in different heavy metal contaminated soil

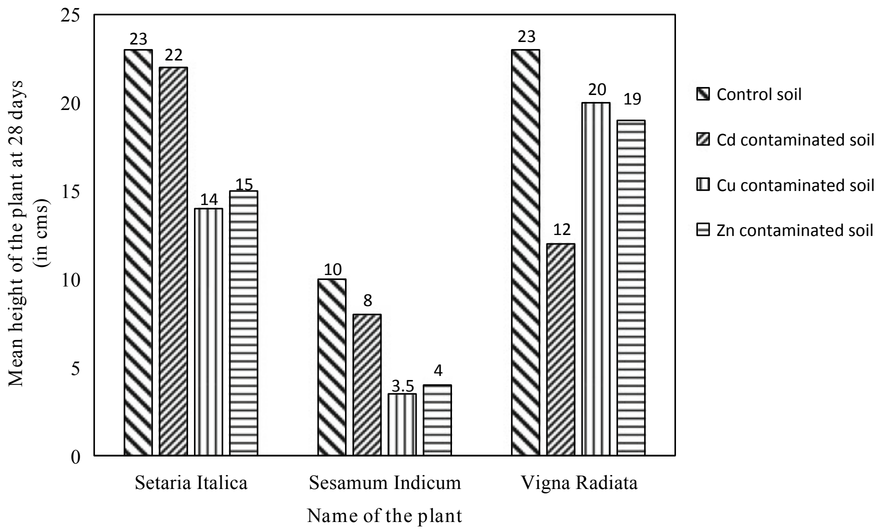


**Fig. 4** Mean height of plant species at 28 days of duration

rate but Vigna Radiata plant had excellent growth in copper and zinc contaminated soils compared to cadmium contaminated soil. Setaria Italica plant is having good growth in cadmium contaminated soil and significant growth in both copper and zinc contaminated soils. Sesamum Indicum plant also having better growth rate in cadmium contaminated soil and half of the growth rate observed in remaining two heavy metal contaminated soils.

The variation of height of Setaria Italica plant for every one week of time interval in different heavy metal. Contaminated soil is shown in Table 3. It has been observed that the Setaria Italica plant is showing phytotoxicity effect in copper contaminated soil.

The growth rate of Setaria Italica plant at every week of time interval in different heavy metal contaminated soils is graphically shown in Fig. 5. Setaria Italica plant is showing linear variation in control soil, cadmium, and zinc contaminated soil; but in copper contaminated soil, it is showing constant growth rate up to 28 days of time.

**Table 3** Mean height of Setaria Italica plant in different heavy metal contaminated soil

| S. No. | Time (days) | Mean height of the Setaria Italica plant (Cms) | | | |
|---|---|---|---|---|---|
| | | Control soil | Cadmium contaminated soil | Copper contaminated soil | Zinc contaminated soil |
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 7 | 0 | 1 | 0 | 0 |
| 3 | 14 | 6 | 4 | 2 | 4.5 |
| 4 | 21 | 15 | 9 | 4 | 10.5 |
| 5 | 28 | 23 | 22 | 4 | 15 |

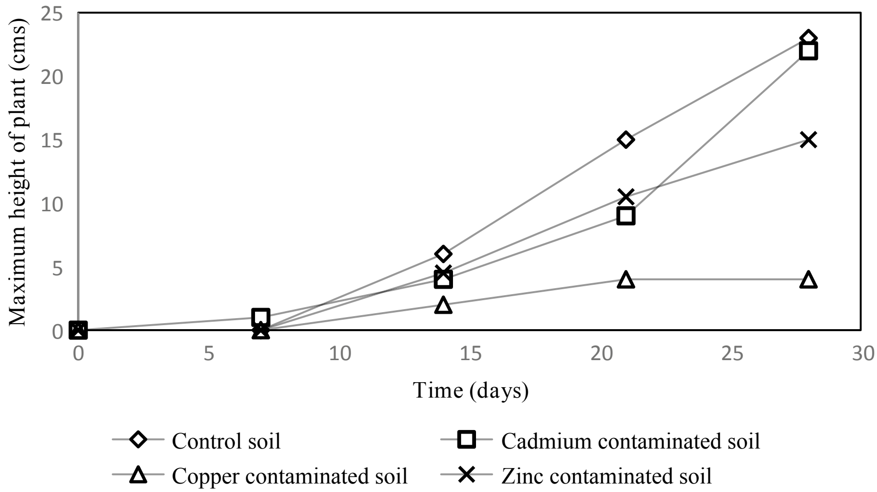


**Fig. 5** Variation of maximum height of the Setaria Italica plant at different days

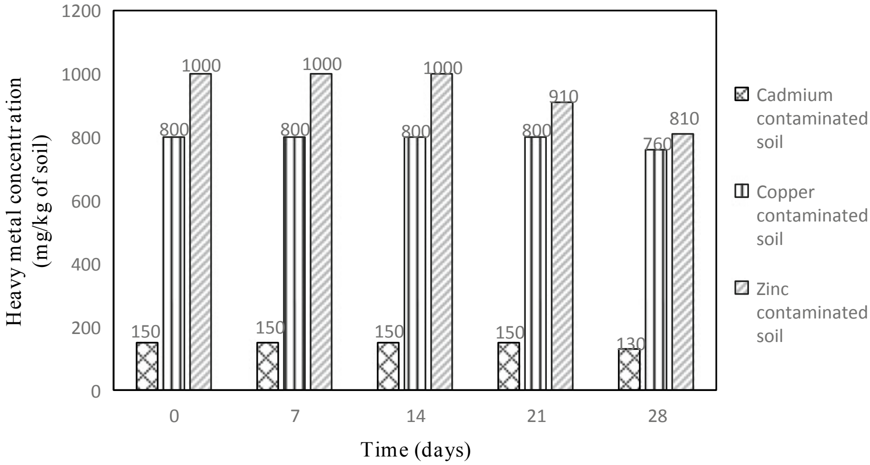


**Fig. 6** Heavy metal concentration present in soil containing the Setaria Italica plant

### *3.4 Heavy Metal Concentration After 28 Days of Duration*

After 28 days of duration, the heavy metal concentration in the pots which contains the Setaria Italica plant was represented in Fig. 6. The reduction of cadmium, copper, and zinc concentrations was 20 mg/kg, 40 mg/kg, and 190 mg/kg of soil, respectively.

The soil sample was collected once in every week from the pots containing the Sesamum Indicum Plant and chemical analysis of soil the sample was carried out, and it was observed that after 28 days of duration the removal of cadmium, copper and zinc concentrations are 11.5 mg/kg, 0 mg/kg and 135 mg/kg of soil, respectively. The heavy metal concentration in the pots containing the Sesamum Indicum plant at every week was mentioned in Fig. 7. Sesamum Indicum plant initiates the removal of cadmium and zinc after 14 days.

The chemical analysis was conducted at every week of duration on soil sample collected from the pot containing Vigna Radiata as phytoremediation plant. The results of chemical analysis were demonstrated in Fig. 8. The removal of cadmium, copper, and zinc after 28 days of duration is 21.31, 18, and 174.22 mg/kg of soil. It has been observed that the removal of cadmium by using Vigna Radiata plant is better than the other two plant species.

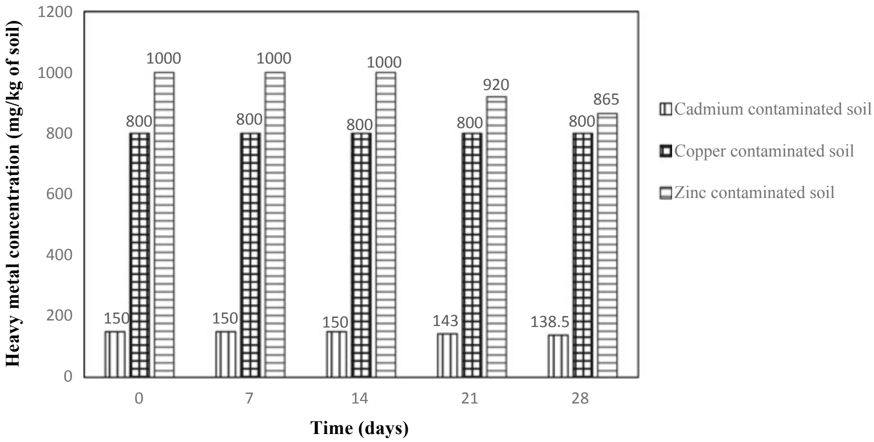


**Fig. 7** Heavy metal concentration present in soil containing Sesamum Indicum plant

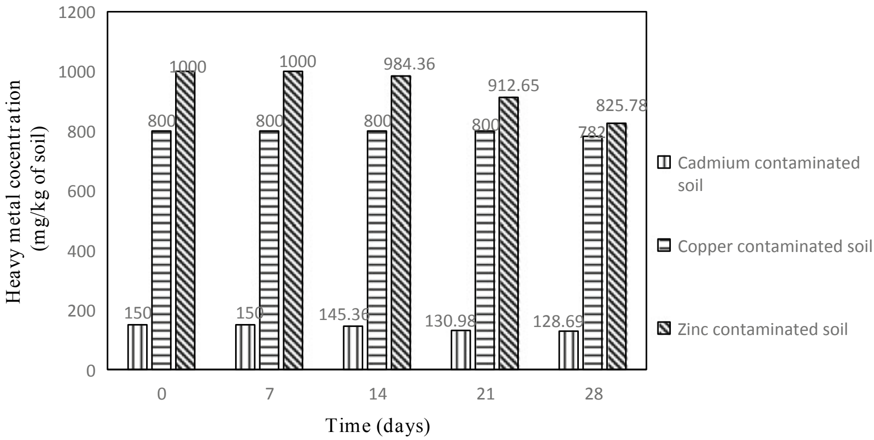


**Fig. 8** Heavy metal concentration present in soil containing Vigna Radiata plant

## 4 Conclusions

From the present study, the following conclusions can be drawn.

1. The percentage germination, and survival of three the selected plant species were significantly affected in Cadmium contaminated soil.
2. After 28 days duration, the degradation of Cadmium, Copper, and Zinc with the Setaria Italica plant was 20, 40, and 190 mg/kg of soil respectively.
3. The quantities of Cadmium, copper and zinc removed by Sesamum Indicum from heavy metal (Cadmium, copper and Zinc) contaminated soils are 11.5, 0 and 135 mg/kg of soil, respectively.

4. The reduction of Cadmium, Copper, and Zinc by using Vigna Radiata as phytoremediation plant is 21.31, 18, and 174.22 mg/kg of soil. From this study, it has been concluded that the removal of Cadmium with Vigna Radiata was significantly better. Overall, the degradation of heavy metals with Setaria Italica plant is excellent, and the removal of Zinc from the Sesamum Indicum plant species is good.

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